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An Analysis of Temporal Evolution of NDVI in Various Vegetation-Climate Regions in Inner Mongolia, China

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Abstract

Inner Mongolia is an important ecological barrier in northern China. The vegetation coverage and changes in the region will directly affect many important economic regions in China. In this paper, based on the long time series NOAA/AVHRR NDVI dataset and vegetation-climate regions map in Inner Mongolia, we utilized the Mann - Kendall non-parametric test to analyze vegetation change treads in different vegetation-climatic regions from 1982 to 2006. The results showed that different vegetation-climate regions had different vegetation change treads. Therein, Central and Western parts of Inner Mongolia had an ascending trend, while, the eastern part had a descending trend. Inner Mongolia span different climatic regions, and plants lived there had various adaptive capacities under different environments. Therefore, its change trends also were quite different. All these illustrate that, under the background of climate change, the sensibility of vegetation are significant different and some plants in different regions have showed their adaptive capacities.

Keywords: Change tread; NDVI; Mann-kendall; vegetation-climate region; Inner Mongolia

1. Introduction

As the main part of terrestrial ecosystems, vegetation is the result of long-term effect by variety natural factors of a region. In the same climatic regions, the heterogeneity of natural conditions is small and the

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vegetation also has certain homogeneity. These provide us an appropriate selection to analyze the vegetation change according to unique phonological characteristics of different regions[1].

Based on the above understanding, this study analyzed vegetation variation in different vegetation-climate regions with Mann - Kendall non-parametric test. The detail and discussion of the method can be seen from the relevant articles [2-4]. Study data were the Chinese climatic regions data (Figure 1) [5] and long temporal series NOAA-AVHRR NDVI sets [6, 7] from 1982 to 2006 with time resolution of 15 days and spatial resolution of 8km in Inner Mongolia Autonomous Region, China.

2. Study area and study data

2.1. Study area

Inner Mongolia Autonomous Region locates in China's northern frontier with area of 1.18×10^6 km^2. Most areas are above 1000 m, so it is called Inner Mongolia Plateau. Vast grasslands distribute in eastern and deserts are mainly widespread in western. The study area spans different climate zones for its vast territory. Average annual temperature is -1～10 ℃ and annual precipitation is about 50 ~ 450 mm. Precipitation gradually decreases from east to west.

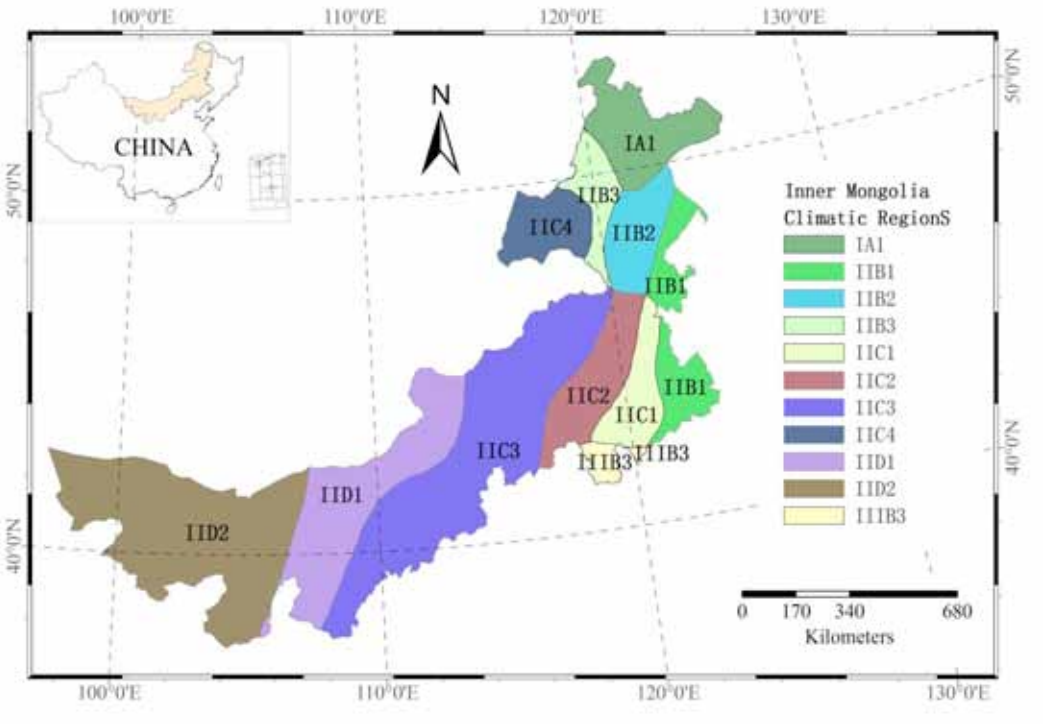

Fig.1. The 11 Vegetation-Climate Regions in Inner Mongolia

This study mainly uses two types of data. One is AVHRR NDVI dataset and another is the vegetation-climate regions map in Inner Mongolia. AVHRR (Advanced Very High Resolution Radiometer) NDVI dataset is produced by the Maryland University research team, GLCF GIMMS. The long time series

NDVI of 1982-2006 is a synthetic data with half-monthly time resolution and 8 km × 8 km spatial resolution. The original data is derived from imagery obtained from the (AVHRR) instrument onboard the NOAA satellite series 7, 9, 11, 14, 16 and 17 (http://glcf.umiacs.umd.edu/data/gimms/). The dataset has been treated by many processes; include radiometric and geometric correction, eliminating a bad line and clouds cover and other process [8]. The Chinese geo-ecological regions data is obtained from a digitized 1:1 000 000 vegetation-climate regions map, which is provided by the Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences [5].

2.2. Study methods

The maximum synthesis value (MSV) method was used to generate monthly maximum NDVI Data. In this paper, maximizing NDVI of summer (7, 8, 9 months) was prepared since it could reflect the current vegetation information as much as possible.

Mann - Kendall non-parametric test [2, 4] is applicable in non-normal distribution, incomplete, or a small number of outlier data. Vegetation changes from one stable state to another and these situations often can be met in time series analysis. Therefore, we detected the change tread by this method. Based on reference [3], the M-K test is based on the test statistic S defined as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{sgn}(x_j - x_i) \tag{1}$$

Where the x_i are the sequential data values, n is the length of the data set, and

$$\mathrm{sgn}(\theta) = \begin{cases} 1 & if\ \theta > 0 \\ 0 & if\ \theta = 0 \\ -1 & if\ \theta < 0 \end{cases} \tag{2}$$

When $n > 8$, the statistic S is approximately normally distributed with the mean and the variance as follows:

$$E(S) = 0 \tag{3}$$

$$V(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{n} t_i i(i-1)(2i+5)}{18} \tag{4}$$

Where t_i is the number of ties of extent i. The standardized test statistic Z is computed by

$$Z_{M-K} = \begin{cases} \dfrac{S-1}{\sqrt{Var(S)}} & S > 0 \\ 0 \quad S = 0 & \\ \dfrac{S+1}{\sqrt{Var(S)}} & S < 0 \end{cases} \tag{5}$$

The standardized M-K statistic Z follows the standard normal distribution with mean of zero and variance of one.

3. Results and discussion

3.1. The NDVI change in different vegetation-climate regions

NDVI mean value reflects the local natural environmental conditions over the years (Table 1), while its range reflects the fluctuation of vegetation over the years. The various vegetation-climate regions were in the following order: IA1 with the value range of [0.7, 0.9]; IIB2 with the range of [0.75, 0.9]; IIB3 with the range of [0.65, 0.85]; IIC2 with the range of [0.45, 0.7] ; IIIB3 with the range of [0.4, 0.7]; IIB1 with the range of [0.4, 0.65]; IIC4 with the range of [0.35, 0.65]; IIC1 with the range of [0.35, 0.55]; IIC3 with the range of [0.3, 0.5]; IID1 with the range of [0.15, 0.25]; IID2 with the range of [0.07, 0.11] (Figure 2).

Table 1. The Vegetation-Climate Regions in Inner Mongolia

Encodes	Climate zones	Mean (NDVI)	Eco-geographical regions
IA1	Humid region, Cold temperate zone	0.83	Morth Daxinganling mountain deciduous coniferous forest region
IIB1	Semi-humid region, Medium temjperate zone	0.55	Middle Songhuajiang and Liaohe Rivers plain forest-steppe region
IIB2	Semi-humid region, Medium temjperate zone	0.82	Middle Daxinganling mountain steppe-forest region
IIB3	Semi-humid region, Medium temjperate zone	0.76	Hill land of north part of west Daxinganling piedmont forest-steppe region
IIC1	Semi-arid region, Medium temjperate zone	0.46	West Liaohe River plain steppe region
IIC2	Semi-arid region, Medium temjperate zone	0.60	South Daxinganling steppe region
IIC3	Semi-arid region, Medium temjperate zone	0.39	East Inner Mongolia mid-altitude plain steppe region
IIC4	Semi-arid region, Medium temjperate zone	0.50	Hulun Buir plain steppe region
IID1	Arid region, Medium temjperate zone	0.19	Hetao and west Inner Mongolia mid-altitude plain desert steppe region
IID2	Arid region, Medium temjperate zone	0.09	Alax and Hexi Corridor shrub and semi-shrub desert region
IIIB3	Semi-humid region, Warm temperate zone	0.59	North China mountain deciduous broadleaved forest region

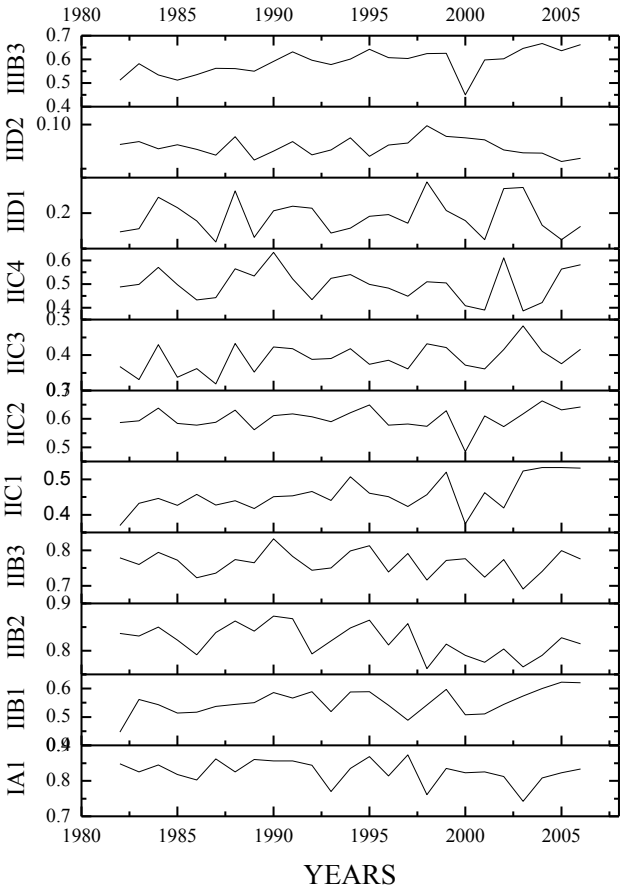

Fig.2. NDVI change in different vegetation-climate regions

3.2. Vegetation trends and mutation testing

NDVI changes curves showed that Vegetation growth had a degradation trend in IA1, IIB2, IIB3, IIC4, IID2 regions. That is, some partial areas of Daxinganling forest, Hulunbeier grassland areas, Alashan and Hexi Corridor had a descend trend, while the Central and Western part of Inner Mongolia had an ascending trend. IIB1, IIC1, IIC2, IIC3, IIIB3 showed the ascend trend. This meant, the NDVI improved region mainly distributed at the mid-eastern part of Inner Mongolia during the study period. IID1, namely Hetao and western parts of Inner Mongolia desert steppe region, its NDVI had little change.

Table 2. Mann-Kendall test for the 11 vegetation-climate regions

Encodes	S Values	Z Values	P Values	Tread	Confidence	Mutational years
IA1	-72	-1.661	0.0967	Descend	95%	1992
IIB1	104	2.407	0.0161	Ascend	99%	---
IIB2	-89	-2.056	0.0398	Descend	95%	1995
IIB3	-17	-0.374	0.7086	Descend	< 90%	1997
IIC1	132	3.061	0.0022	Ascend	99%	---
IIC2	41	0.935	0.3498	Ascend	< 90%	2002
IIC3	54	1.238	0.2155	Ascend	< 90%	1990
IIC4	-27	-0.607	0.5436	Descend	< 90%	1996
IID1	1	0	1	--	--	---
IID2	-36	-0.821	0.4115	Descend	< 90%	2001
IIIB3	180	4.181	0	Ascend	99%	---

4. Conclusion

The study showed that: 1) Inner Mongolia was divided into 11 Vegetation-climate Regions. The NDVI values and ranges had a big difference among the respective regions, indicating that spatial distribution of vegetation was obvious difference. 2) The inter-annual changes of NDVI are different in different vegetation-climate regions. Some partial areas of Daxinganling forest, Hulunbeier grassland areas, Alashan and Hexi Corridor had a descend trend, while the Central and Western parts of Inner Mongolia had an ascending trend.

In the study area, some researchers analyzed the ecological changes with the different method [8, 9], comparing to the previous studies, our conclusions are basically consistent with them.

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References

[1] Liu JY, Zhuang DF, Luo D, Xiao X. Land-cover classification of China: integrated analysis of AVHRR imagery and geophysical data. *Int J Remote Sens* 2003;**24**:2485–500.

[2] Mann H. Nonparametric tests against trend. *Econometrica* 1945;**13**:245–59.

[3] Yue S, Pilon P, Cavadias G. Power of the Mann–Kendall and Spearman's rho tests for detecting monotonic trends in hydrological series. *J Hydrol* 2002;**259**:254–71.

[4] Kendall M. *Rank correlation measures.* Charles Griffin, London; 1975:202.

[5] Zheng D, Li B. *China's eco-geographical region map*. Beijing:The Commercial Press; 2005.

[6] Pinzon J, Brown M, Tucker C. Satellite time series correction of orbital drift artifacts using empirical mode decomposition. In: Huang NE, Shen SSP editors. *Hilbert-Huang Transform: Introduction and Applications*, Singapore: World Scientific Inc; 2004, p. 173–6.

[7] Tucker C, Pinzon J, Brown M, Slayback D, Pak E, Mahoney R, Vermote E, Ei Saleous N. An extended AVHRR 8-km NDVI dataset compatible with MODIS and SPOT vegetation NDVI data. *Int J Remote Sens* 2005;**26**:4485–98.

[8] Hu Y, Liu JY, Zhuang DF, Yang FT. Study on the relationship between land-use dynamics and wind erosion dynamics in Inner Mongolia during late 1990s. *Prog geogr* 2003;**22**:541–50.

[9] Lee R, Yu f, Price KP, Ellis J, Shi P. Evaluating vegetation phenological patterns in Inner Mongolia using NDVI time-series analysis. *Int J Remote Sens* 2002;**23**:2505–12.